United States Department of the Interior, J. A. Krug, Secretary
Fish and Wildlife Service, Albert M. Day, Director

Fishery Leaflet 325

Washington 25, D. C. November, 1948

THE NUTRITION OF FISH IN HATCHERIES--A LITERATURE REVIEW

By Neva Karrick, Chemist,
Seattle Technological Laboratory,
Branch of Commercial Fisheries

- - - - - - - - -

Contents

Page

Introduction.......... 1
Mechanics of Feeding.......... 2
Anti-Anemia and Growth Factors.......... 3
Nutrients.......... 4
The Vitamins.......... 5
Methods of Preservation.......... 7
Salmon By-Products.......... 8
Other Foods.......... 9
Literature Cited.......... 11

INTRODUCTION

The objective of workers in the field of the nutrition of fish has been to find inexpensive and easily obtainable foods which not only keep the fish alive and growing at a normal rate, but also keep them healthy and in good condition, so that they will survive when released from the hatchery. With the increasing demand for hatchery-bred fish, the necessity of having available large sources of inexpensive and nutritionally adequate food has also become more imperative. In the past, animal livers and similar fresh meat products have been one of the principal ingredients in the standard diet for hatcheries. It has been known that the liver diet is not the perfect food, and fish reared on the liver were not as healthy and vigorous as the fish growing in their native habitat upon natural foods. However, certain livers were available and inexpensive through the use of material condemned as unsuited for human food, and no better diet was known. The higher prices and the scarcity of sufficient liver and similar meat by-products to supply the increased hatchery demand have eliminated the advantages of using these materials for food, so that workers have been searching for other substances which contain the factors necessary for optimum fish growth.

In order to get an indication of the type of food needed and eaten by fish, the stomach contents of wild fish have been examined by a number of workers (1-20). The evidence points to the fact that salmon and trout eat what food is available; for example, plankton, algae, crustaceans, young insects, protozoa, copepoda, and smaller fish. Ordinarily, there is no evidence of selection of available food other than the necessary basis of the relative sizes of the fish and the available food supply. When some of these natural foods are added to hatchery diets, the fish appear to thrive upon them (21,22,102). Since it is not always practical to feed these foods on a large scale, the nutritional elements which promote the growth of the fish must be found from other sources.

Many difficulties are encountered by the person who attempts to establish a balanced diet. The fish require too many factors which are as yet unknown to those working on fish nutrition. It has not been possible to rear fish for any length of time upon a diet consisting of substances with a definitely known composition.

MECHANICS OF FEEDING

In determining the value of a diet, there are many variables other than the diet itself which must be controlled and whose optimum conditions must be determined. Some of these variables are: the amount and manner of feeding; the consistency of the diet; the temperature, pH, and cleanliness of the water; the number of fish per cubic foot of water; and the size of the fish being given the diet (22-28). Since it is difficult to determine accurately the growth of the fish and to ascertain their state of health and condition, slight variations in measuring these effects may cause errors in an evaluation of the diet.

The amount of food given is determined by the size of the fish and the temperature of the water. Small salmon feed on particles suspended in the water and they are fed often (29). However, if too much food is given, there is inefficient utilization of the food (27). Overfeeding the fish will result in sluggish, unhealthy fish despite the fast growth rate. It is particularly easy to overfeed fish when meat meals or fish meals are fed (31-34).

The consistency and form of the diet to be fed is of utmost importance. If it is too liquid, the water soluble products will be dissolved before the fish eat them, and binders, such as salt or apple pomace must be used to avoid this. If it is too dry, they will not be able to break it up (27). The size of the food particles is of importance, and increasing the particle size as the fish grow may also be necessary. The food particles must be light enough to stay on the surface for a short time and then sink slowly to the bottom. Various mechanical methods of preparing the food have been developed, such as forcing the feed through a potato ricer to give the appearance of worms (26,35), grinding the food in a meat grinder and then breaking this extruded material into pellets (36), or putting it in a blower driven about 5000 r.p.m. to thoroughly mix the meat and meal (114). There is some disagreement regarding the proper time to begin the inclusion of dry meals in the diet. Some workers use dry meals from the time the fish begin to feed (37), others believe that the fish should be at least two inches long before dry meals are incorporated into the diet (33,38). When meals plus fresh meat are added to the diet, the meal must be thoroughly moistened and the two components should then be thoroughly mixed (27,38).

Regardless of how carefully the diet is prepared, this preparation does not determine how much food each fish will consume, but only how much is available. In order to remedy this situation, attempts have been made to feed each fish a definite quantity of food by filling gelatine capsules with the desired amount of food and inserting the capsule into the stomach of the fish using small forceps. The gelatin itself has nutrient value and, although the diet was still somewhat deficient, the growth rate of fish fed the diets not containing fresh meat increased (39,43). Small stomach tubes have also been used, but they were unsatisfactory.

ANTI-ANEMIA AND GROWTH FACTORS

Raw fresh meat contains a substance or combination of substances which are essential for sustaining life and for growth. These are known as "Factor H" (44,45). Lack of "Factor H" results in anemia and death (99). The substances may be separate and distinct from the known vitamins (44,46, 47) or they may be made up of a definite proportion of vitamins and/or amino acids or other substances. Diets containing a sufficient supply of vitamins A,C,D,E, and the vitamin B complex (44) and a basal diet of heat-treated casein, starch and salts (calcium carbonate, 25; bone meal, 30; sodium chloride, 25; magnesium carbonate, 5; potassium monohydrogen phosphate, 15; and a trace of potassium iodide) (43) did support life, and there was growth, but anemia developed. The required substances have not been isolated as yet, but when the alcohol, acetone and ether extracts of liver have been added to diets which of themselves would not support growth, the fish have grown (43,48). "Factor H" is heat labile and it is destroyed by ordinary drying (45). However, it has been preserved in spray-dried skim milk (44), in liver which was lyophilized or dried in air at a low temperature (49) or vacuum-dried in an inert gas (45), and in fish flesh dried for about 10 hours at a temperature which did not exceed 140°F. (50,51). It has been suggested that these dried products be stored under carbon dioxide to protect "Factor H" (49).

The presence of the growth factors has been demonstrated to a greater or lesser degree in many animal tissues and possibly it is present to some extent in all living tissue. It is known to occur in beef, pork and sheep liver, spleen, heart, lungs, kidneys, and melts (49,52), skim milk (44,53, 54), the eggs, viscera and possibly carcasses of salmon (22,51), fly maggots (55,56), midge and mosquito larvae (26). Phillips et al said the pork or beef spleen was as effective as beef liver for the prevention of anemia (120). Muscle tissue is not as good a source of "Factor H" as are the organs of animals (99). Hewitt (57) attempted to identify "Factor H" on the basis that since certain phosphatides are present in all living tissues, one or a combination of them may be "Factor H". He fed 40 trout a diet of steamed dried silkworms, and stated that when he added lecithin and cephalin to the diet the trout showed an increase in growth and no mortality for 6 months.

Despite the asserted destruction of "Factor H" by heat, there are records of diets which consisted entirely of cooked food permitting growth. The statement has been made that hatcheries feeding the cooked food had fewer losses than those feeding raw liver; in some cases, supplementary vitamins were added to the cooked food and in some cases they were not (58). Fish fed a diet balanced in protein, fat, carbohydrates, minerals, and vitamins will maintain good growth with low mortality if fresh meat is added periodically. The growth curves were practically the same whether fresh meat was added to the diet daily, weekly or bi-weekly (53,55). Tunison et al (40) attempted to develop an assay for "Factor H" by feeding a synthetic diet containing: raw starch, 34; dextrin, 34; casein, 20; mineral mixture, 4; yeast, 5; and cod liver oil, 3. This synthetic diet produced the anemia which is characteristic in fish suffering from a "Factor H" deficiency. He found that the fish died when the red cell count was less than 700,000 per cubic millimeter. After feeding this diet for 4 weeks, he added various amounts of liver. The anemic group of fish which were fed 100 percent liver sustained no further excessive mortality. Subsequent tests of various liver extracts, autolyzed beef liver, raw liver, and fly maggots indicated that of these materials, the raw liver and fly maggots could cure and prevent the anemia of fish. In feeding tests conducted one year, the liver extracts increased the red cell count, but the same effect could not be duplicated later (55,56,59).

It is possible that fly maggots (56) and insect larvae (26) contain one of the pterins which may help to cure or prevent anemia in fish. Norris and Simmons (60,61) found that the injection of xanthopterin into anemic fingerling salmon resulted in an increase of erythrocytes up to an approximate maximum of 1,600,000 per cubic millimeter and that there was a positive correlation between the amount of xanthopterin given and the increase in the number of red cells. The workers at the Cortland Hatchery (59) were not able to increase the red cell count of trout by feeding xanthopterin. McLaren et al reported that when folic acid and biotin were added to a diet which produced anemia, no anemia developed.

NUTRIENTS

Attempts have been made by many workers to determine the identity and amount of the various nutrients needed by fish. The requirements of trout and salmon are those which we have reviewed for this report.

McCay found that a 14 percent level of protein in the diet was necessary for growth (30,62) and that more than 25 percent protein in the diet did not increase the rate of growth (46,62). There was a greater utilization of protein with diets containing the lower levels of protein (64) or if 7 percent fat was added to the diet (28). The source of the protein was found to affect its utilization by the fish. Animal protein was better utilized than the protein from vegetable sources (59). There was considerable variation in the utilization of protein from the different kinds of meat, but this may be due to the fact that some meats were more difficult than others to prepare in a form that the fish would eat readily. (65).

The suggested amount of fat to be included in the diet is 5-8 percent (66). However, McCay showed that whether 7 or 25 percent of fat was added to the diet of trout, 80 to 90 percent of the fat was digested (30). The lower melting point fats, cottonseed oil and salmon oil, were utilized slightly better than the hydrogenated fats such as Crisco (27,67). The feeding of diets having a high fat content resulted in the degeneration of the pancreas (68,69). The livers of fish fed diets containing either 100 percent liver, or cholesterol, or a high fat or high carbohydrate content showed great deposits of fat in the liver. This fat storage was decreased by the addition of vitamin C or choline to the diet (48,69).

Trout can utilize carbohydrates to some degree, but ordinarily, if they are fed diets containing more than 20 percent carbohydrate, they develop large livers with a high percentage of glycogen (40,41). However, other workers report that diets containing 45 percent carbohydrates have been fed without the development of the enlarged livers. The destructive changes observed in the pancreas and attributed to the use of a diet having a high carbohydrate content were prevented by the addition of choline to the diet (69). Phillips et al recommended that trout be fed not more than 9 percent digestible carbohydrate in the diet, or not more than 4.5 grams digestible carbohydrate per kilogram of body weight per day. It is possible that trout and salmon cannot utilize more carbohydrate because they have fewer islets of Langerhans than other animals. Trout and salmon had different rates of absorption of carbohydrate, but this may have been caused by other variables, such as a difference in the water temperature or the size of the fish (119).

Very little work has been carried out to determine the optimum mineral content of a diet. McCay and his co-workers (49) did show that the addition to the diet of a mixture consisting of equal parts bone meal, sodium chloride, and calcium carbonate was beneficial. They also demonstrated that fish absorb calcium from the water (70) and therefore the need for calcium in the diet is contingent upon the amount of calcium available in the water (27). Feeding diets which had a high calcium content and a low phosphorous content did not cause rickets or a similar disease (49). It was also found that while ferrous sulphate was toxic to anemic fish, other iron compounds did not affect them and that none of the iron compounds had any effect on normal fish (59). Zinc sulphate, copper sulphate, potassium iodide, and ferric citrate, plus cod liver oil and wheat germ when added to dried skim milk resulted in no better growth than the dried skim milk alone had produced (30). Kelp meal added to a deficient diet of fluky beef liver improved the condition of the fish. The kelp meal is a good source of the minerals and of the vitamin B complex (71,72).

When roughage has been included in the diet, lower mortality has resulted, but the reasons for this effect, which would establish the actual value of roughage, have not been determined (73). Other tests indicated that when the amount of roughage was greater than 25 percent, the growth of the trout decreased (54). Substances which have been added to the diet for roughage and bulk include oat flour (74), cellulose (54), apple flour (75-78), alderwood sawdust (75), beechwood sawdust (79), diatomaceous earth (79), agar-agar (44), and cereals (80). Bulk added to the diet may lessen the dangers of overfeeding and forestall the resulting degeneration of the pancreas and liver (41,76).

THE VITAMINS

Since no synthetic diet has been developed due to the lack of knowledge of some of the essential growth factors and conditions of life, determination of the vitamin requirements has been almost impossible (24). When crystalline vitamins are fed there is no feasible way of determining how much of these vitamins is lost through solution and how much the fish eat. In order to reduce this loss of vitamins, 12.5 percent each of raw corn starch and dextrin were added as binders (28). The ability of the fish to utilize vitamins from different sources is an unknown variable and the recognition of deficiencies attributable to the lack of a specific vitamin is often difficult.

The addition of yeast and cod liver oil to diets containing (a) varying amounts of casein, cooked starch, dextrin, minerals, and (b) fish meal and dextrin resulted in inadequate diets (41,49,54,73). When 21 percent liver was added to fish meal and dextrin, the diet was satisfactory. Tomato juice added to diet (a) did not sustain life (45). When yeast, cod liver oil and carrot juice were added to autoclaved raw meat, the diet did not promote growth or sustain life. The yeast plus the unautoclaved meat did not produce any better growth than the unautoclaved meat alone (81). Others added 3 percent cod liver oil to varying proportions of fish meal and liver and found that it improved growth (32,62). Titcomb et al (73) stated that fish need some of the ingredients of yeast and cod liver oil, but that it is more satisfactory to get them from another source.

Trout store and lose vitamin A very slowly. Those fed beef liver store much more than those fed beef spleen. The addition of carotene or cod liver oil to various diets did not improve the storage of vitamin A as did the addition of beef liver to the diet (55,82). Cod liver oil added to both raw and cooked beef liver at levels of 2 and 5 percent did not affect the growth (83). A study of cataracts appearing in trout showed that the cataracts were due to a nutritional deficiency. They were present when diets of 100 percent beef spleen were fed, but did not appear when any beef liver was in the diet (115).

Hewitt (66) stated that vitamin C in the diet increases the growth and decreases the mortality, particularly when included in a high fat diet. Haempel and Peter (84) stated that vitamins B and C are necessary for fish 2 and 3 years old. However, another worker (85) found that vitamin C had an unfavorable effect when added to a diet which consisted of waste, 95; flake potato, 4; and calcium phosphate, 1.

The requirement for vitamin D has not been determined.

The requirements of fish for the B vitamins have been studied more extensively than the requirements for the other vitamins. Early observations had been made that the addition of yeast protected the fish from gill disease (81), and that the growth and vitality were improved by the addition of the vitamin B complex. (86, 87).

Workers at the Cortland Hatchery have attempted to establish the requirements of these vitamins for trout by feeding various amounts of the vitamins and after varying periods of time, assaying the organs of the trout to determine maximum storage. Thus the daily amount of vitamin intake necessary for maximum storage was determined and a tentative requirement for the vitamin was estimated (28). It was acknowledged that these values were only approximate and that all the vitamins tested may not be necessary for the production of healthy fish. The assays on the organs of the fish were run microbiologically.

Anemic fish were fed a solution containing calcium pantothenate, riboflavin, pyridoxine, thiamine hydrochloride, niacin, and biotin (28). The first year there was regeneration of the red blood cells; but it was not possible to repeat these results the second year. It has been suggested that possibly the time of year, the temperature of the water, the size of the fish, and variations in the yeast and casein included in the synthetic diet may have been factors which affected the results.

Fish kept in water at 47° F. required a thiamine intake of 0.115 to 0.125 milligrams per kilogram of body weight per day for maximum storage. Those kept in water at 52° F. required 0.150 to 0.168 milligrams per kilogram of body weight per day.

Fish have been observed to have a specific disease with known characteristics which can be cured and prevented by adding thiamine to the diet (88,89). It is not an anemia, but rather a disease of the nervous system (88). The inclusion of certain fresh fish in the diet will cause this disease (22, 55, 88-94). These fish contain an enzyme which destroys the thiamine in the food (90,95-98). Methods of feeding fresh fish in order to avoid this avitaminosis are (88): (a) feeding the fresh fish only on alternate days, (b) feeding the diets containing fresh fish to the fish immediately after mixing with the other ingredients, (c) adding yeast containing a high thiamine content, and (d) cooking the fish.

It was necessary to feed from 0.30 to 0.68 milligrams of riboflavin per kilogram of body weight per day for maximum storage. Riboflavin from plant concentrates was better utilized than that from animal concentrates. Low riboflavin content in the diet did not cause anemia in the fish (24,28).

It was necessary to feed from 0.225 to 0.250 milligrams of pyridoxine (28) and 3.0 to 4.1 milligrams of niacin per kilogram of trout per day to obtain maximum storage. The biotin requirement varied with the species of trout being fed (120).

It was found that 0.99 to 1.45 milligrams of pantothenic acid per kilogram of body weight was required for maximum storage (24,28). Lack of pantothenic acid resulted in a non-bacterial gill disease (28,86).

When a deficient diet was supplemented with folic acid, the diet was not improved (120). The addition of folic acid plus biotin was said to prevent anemia (116). Folic acid plus pyridoxine, pantothenic acid, and riboflavin given to anemic fish seemed to alleviate their symptoms, but did not cure the anemia (99).

METHODS OF PRESERVATION

Trout have been fed meat which had been preserved for a long period of time with 1 percent formalin (82), and with calcium hypochlorite (67), and apparently no ill effects resulted. Hydrochloric acid was tested as a preservative but this treatment hydrolyzed the meat and turned it into a soup (82). Antiseptics have also been included in the diet (53,100). It is reported that 0.2 percent mercurous chloride, 0.2 percent carbon tetrachloride, 0.5 percent hexamethyleneamine, 0.5 percent beta naphthol, 0.5 percent creosote, 0.5 percent salol, 0.5 percent sodium sulphocarbolate, 5 percent chlorinated liver, and 3 percent formaldehyde in liver were not harmful when added to the diet in the amounts stated above. Neither the maximum dosage nor the length of time that the antiseptics could be fed was determined. Resorcinol was toxic to trout at the 0.5 percent level, but non-toxic at the 0.1 percent level. One percent sodium bicarbonate was harmful to the fish. McCay et al (30,54) found that meat preserved with 10 percent alcohol retained the growth factor. They (49) then fed fish a diet of equal parts of dried skim milk and liver dried at a low temperature, plus 10 percent ethyl alcohol. These fish began to fail after 48 weeks. Fish fed the same diet without the ethyl alcohol were in excellent condition after 60 weeks.

Dried fish and animal meals are often used as a substantial part of diets fed fish. Reports of the value of meals from a particular source will often vary considerably. The preparation of a meal will often be the determining factor in its nutritive value, and consequently, it is necessary to know the method and conditions of the preparation of a meal before evaluating it as a supply of food for the fish. Fish and fish waste such as that from cod, haddock, and hake, which have a low fat content, and some salmon waste, is cooked to coagulate the protein and then may be dry-rendered to the finished meal stage directly without the removal of oil. If the oil content of the dry meal is excessive, the oil may then be removed by a hydraulic press.

Meat and animal waste may be cooked with steam and pressed to remove the fat, after which the pressed material is dried by direct heat or by indirect (steam) heat. Some plants remove the fat from the cooked and semi-dry meat waste by the use of a solvent extraction stage. The solvent-oil mixture is drawn off and by means of heat and vacuum, the solvent and most of the moisture remaining in the meal is removed. Usually, a temperature not to exceed 150°F. is used during this drying process.

The meals prepared from herring, menhaden, and sardine are cooked, the moisture and oil pressed out by mechanical means, and the pressed material dried by application of direct or indirect heat. In the final step of this process the meal will reach a minimum temperature of 250° F. and will often be as high as 350° F.

SALMON BY-PRODUCTS

Salmon has been prepared in a number of different ways for incorporation in fish diets. These include salmon carcass meal, both vacuum-and flame-dried; salmon egg meal; fresh and frozen salmon viscera; fresh, frozen and canned salmon flesh; and fresh, canned, dried, frozen, and mild-cured salmon eggs. These were fed alone and in various combinations with each other and with other foods. Salmon eggs were found to give good color and growth, but they cause a high mortality when fed alone (22,29,101). Equal parts of raw spawned-out salmon carcasses plus the fresh eggs decreased the mortality but there was subnormal growth, while canned spawned-out salmon carcasses plus the fresh eggs permitted good growth and low mortality (29). The feeding of mild-cured eggs resulted in a low mortality rate, but there was a poor growth rate (29), and diets of fresh salted salmon eggs caused high mortality and poor growth (101). The frozen eggs permitted good growth when mixed with raw liver, but poor growth when mixed with the canned salmon (102). Fish fed dried salmon eggs had a good color and grew rapidly (103) but after 3 or 4 months they began to show a high mortality rate and the diet had to be discontinued (37). However, when dried salmon eggs or salmon egg meals were included in diets containing fresh meat, the growth was good and the mortality was low (21,32,33,35,37,101,102,104,105). There was a report of a diet containing 50 percent hog spleen and 50 percent of the following mixture: 25 percent each of dried skim milk, cottonseed meal, whitefish meal and salmon egg meal, and 4.0 percent salts. The feeding of this diet resulted in high mortality. The bodies were coated with slime and symptoms of a gill disease were present, so factors other than the diet may have caused the increased death rate (40).

Including salmon viscera in a diet causes it to become quite fluid. Consequently, on this diet results vary greatly with the manner of feeding (106). Fish fed salmon viscera which had been frozen for 1½ years showed as satisfactory growth response after 20 weeks as those fed diets composed entirely of beef liver (31,34,77). Salmon viscera evidently contains some anti-anemia factors, although not as much of these factors as does beef liver. Salmon flesh does not possess the factors which prevent anemia and when fed in large amounts a lowered erythrocyte count and higher mortality rate result (106). When salmon were fed 100 percent salmon viscera, there was a smaller deposit of fat in the pancreas than in those fish which were fed 100 percent beef liver. The pancreatic tissue in the former fish, however, was in the initial stages of breakdown. When fish were fed a diet containing 1/3 each of beef liver, salmon viscera, and seal meal, the pancreatic tissue was very similar to the pancreatic tissue of wild fish (69).

Other satisfactory diets which contain salmon products have been reported. These include: canned salmon mixed with an equal portion of beef liver (51,102) or spleen (107); 33 percent raw beef liver plus frozen salmon offal, canned salmon, or fresh, frozen, or dried salmon eggs (102); canned salmon and dried salmon eggs in 50-50 or 75-25 proportions (102). Diets of frozen spawned-out salmon flesh mixed with beef spleen, low-temperature dried salmon meal or salmon liver resulted in high mortality and poor growth (101). The salmon meal prepared commercially, at high temperatures, was a very poor addition to a diet (51,102), but excellent results were obtained if the salmon meal was prepared at low temperature and fresh meat was added (32,51,74,75,78,101,107,108).

OTHER FOODS

A number of different substances have been added to the diet of the fish in the hope that the fish will live and grow well. Some of these products are:

A. Dried skim milk. Dried milk and fish meal was a good diet if sheep plucks were added once a week. A dried milk diet will support growth for a limited period of time (30,40,53,54,59,65) but fresh meat must be fed at least every two weeks. It was believed that the deficiency in the dried milk diet was not due to a lack of any of the vitamins with the possible exception of vitamin C. Dried buttermilk and dried skim milk have been used interchangeably in fish diets (33,53,109).

B. Meals other than fish or meat meals. No vegetable meal has been so effective a source of protein as have the fish or meat meals. Of the vegetable meals which have been used, linseed meal has proved to be toxic (73). Other workers have disagreed as to the value of those vegetable meals which they have tested. These include soybean meal (55,59,73), cocoanut meal (73), cottonseed meal (30,33,40,59,73,103), corn glutten meal (59,65), and wheat flour middlings (40,59). Alfalfa meal (32,54) and watercress (72) added to the diet did not improve the growth while the addition of kelp meal seemed to improve the growth (32,71,72). Haempel and

Peter (84) stated that sprouted seeds were more digestible than unsprouted seeds, but other workers have found the opposite to be true (32,41).

C. Meat and meat meals. Horse meat including the liver, spleen, and kidneys has been said to be good trout food (33,101), but others have reported that horse meat fed at high levels did not permit normal growth (113). Fresh blood has been added to the fish and meat meals with beneficial effects, possibly due to the moistening of the meal (75,85,108). Dried meat scrap and animal waste dried at a high temperature lacked "Factor H" (53).

D. Fish and fish meals, exclusive of salmon.

(1) Ground shrimp (38,58,109) and clam heads (38,65,80) have been reported to be satisfactory supplements to a diet.

(2) Seal meal, which was prepared in a manner similar to that used for meat meals, seemed to be of doubtful value (40,69,78,104).

(3) One year a diet which consisted of one-half abalone meal and one-half liver was found to be better than the 100 percent liver diet, but the next year a high mortality resulted when this same diet was fed (110,111).

(4) Diets composed entirely of sardine meal prepared by a vacuum process, and of 90 percent of the sardine meal plus 10 percent liver resulted in an avitaminosis which was cured by the addition of fresh meat to the diet (52).

(5) Fish fed carp meals made from raw and from cooked carp grew better and had lower mortality during the 7 weeks of the experiment than those fed liver (101).

(6) Diets of herring meal plus fresh beef liver yielded almost the same results as those consisting of salmon meal plus the fresh beef liver. Diets containing dogfish, tuna or pilchard meals gave poor results. The addition of dogfish liver oil to the meals did not improve any of the diets (112).

(7) When whitefish meals were included in the diets, good results were obtained when fresh meat was also incorporated. The fish meal was a good source of protein and calories, but did not contain "Factor H" (49,53,105).

(8) Fish meal prepared by vacuum drying cod and haddock waste was fed at 30 and 40 percent levels and resulted in fair growth (32).

There is much work still to be done before a definite statement can be made about the composition of an adequate diet for fish. However, it has been shown that fish can utilize diets containing waste from salmon in the fresh, frozen, cooked, or dried meal forms. Properly prepared salmon meals and the frozen waste are certainly an important potential source of a food for inclusion in hatchery diets.

LITERATURE CITED

(1) RANEY, E. C., and LACHNER, E. A.

1941. Autumn food of recently planted young brown trout in small streams of central New York. Trans. Am. Fish. Sec. 71, 106-111.

(2) RICKER, W. E.

1937. The food and the food supply of sockeye salmon (Oncorhynchus nerka Walbaum) in Cultus Lake, British Columbia. J. Biol. Bd. Can. 3, No. 5, 450-468.

(3) IDYLL, C.

1942. Food of rainbow, cutthroat and brown trout in the Cowichan River system, British Columbia. J. Fish. Res. Bd. Can. 5, No. 5, 448-458.

(4) IDE, F. P.

1942. Availability of aquatic insects as food of the speckled trout, Salvelinus fontinalis. Trans. North Amer. Wildlife Conf. 7, 442-450.

(5) GLASS, J. T.

1935. Growth of fingerling trout in natural lakes in Wyoming. Univ. of Wyoming Pub. 2, No. 3, 17-30; Biol. Ab. 18, 15545 (1944).

(6) FOERSTER, R. E.

1933. The importance of copepoda in the natural diet of sockeye salmon. Proc. 5th Pacific Sci. Congress (Canada) 3, 2009-2016.

(7) CHURCHILL, W. S.

1944. The food of trout. Wisconsin Conserv. Bull. 9, No. 5, 3-6.

(8) CHAPMAN, W. M., and QUISTOrFF, E.

1938. The food of certain fishes of north central Columbia River drainage, in particular, young chinook salmon and steelhead trout. Dept. Fish. Washington, Biol. Rept. 37A, 1-14.

(9) ANONYMOUS

1934. The food of young spring salmon in Shuswap Lake, British Columbia. Can. Field Nat., Vol. XVIII, No. 9, p. 142.

(10) RICKER, W. E.

1934. Plankton organisms and their relation to the sockeye of Cultus Lake. Prog. Rept. Pac. Biol. Sta. Can. No. 21, 14-16.

(11) WELLES, G. D.

1944. Trout and their favoite food. Game Breeder and Sportsman 49, No. 7, 78-79, 84-85.

(12) MOTTLEY, C. McC., and MOTTLEY, J. C.

1932. The food of the Kamloops trout. Prog. Rept. Pac. Biol. Sta. Can. No. 13, 8-12.

(13) WEBSTER, D. A., and LITTLE, G. S.

1944. Further observations on the food of newly planted brown trout (Salmo trutta) in Six Mile Creek, near Ithaca, New York. Copeia, No. 1, 56-57.

(14) WEBSTER, D.A., and LITTLE, G.S.

1942. Food of newly planted adult brown trout (Salmo trutta) in Six Mile Creek near Ithaca, New York. Copeia, No. 3, 190.

(15) RANEY, E. C.

1942. The summer food and habits of the chain pickerel (Esox niger) of a small New York pond. J. Wildlife Management 6, No. 1, 58-66.

(16) RANEY, E.C., and LACHNER, E. A.

1942. Studies of the summer food, growth, and movements of young yellow pikeperck, Stizostedion v. vitreum, in Oneida Lake, New York. J. Wildlife Management 6, No. 1, 1-16.

(17) PRITCHARD, A. L., and TESTER, A. L.

1944. Food of spring and coho salmon in British Columbia. Fish Res. Bd. Can. Bull. 65, 23 pp.

(18) CHAPMAN, W. M.

1936. The pilchard fishery of the State of Washington in 1936 with notes on the food of the silver and chinook salmon off the Washington Coast. Dept. of Fish., State of Washington, Biol. Rept. 36C, 20-30.

(19) BURKHOLDER, P. R. and BERE, RUBY.

1933. Biological survey of the upper Hudson watershed. VIII. Plankton studies in some lakes of the upper Hudson watershed. N. Y. State Conserv. Dept., Biol. Survey, Suppl. Ann. Rept. 22, 239-263.

(20) CHEVEY, P.

1932. Sur la nature de l'influence exercée par la foret inondée du Grand Lac du Cambodge sur la vitesse de croissance de poissons. Compt. Rend. Acad. Sci., 195, No. 23, 1108-1110; Biol. Ab. 8, No. 8, 19147 (1934).

(21) AGERSBORG, H. P. K.

1934. An inexpensive balanced diet for trout and salmon. Trans. Am. Fish. Soc. 64, 155-162.

(22) AGERSBORG, H.P.K.

1934. Qualitative and quantitative analyses of foods for salmonoids reared artificially. Trans. Am. Fish. Soc. 64, 435-442.

(23) TUNISON, A. V. and McCAY, C. M.

1935. The nutritional requirements of trout. Prog. Fish. Cult. No. 11, 17.

(24) PHILLIPS, A. M.; TUNISON, A. V.; SHAFFER, H. B.; WHITE, G. K.; SULLIVAN, M.W.; VINCENT, C.; BROCKWAY, W. R.; and McCAY, C. M.

1945. The nutrition of trout. Fisheries Research Bull. No. 8, N. Y. State Conserv. Dept., Albany, N. Y., Cortland Hatchery Rept. No. 14, 28 pp.

(25) STILES, E. W. and RUSS, H. C.

1938. Meat diet supplements, and their effect on growth and health of fingerling trout. Prog. Fish. Cult. No. 37, 10-16.

(26) A SYMPOSIUM

1923. Foods and feeding of fishes. Trans. Am. Fish. Soc. 53, 137-159.

(27) TUNISON, A. V., and McCAY, C. M.

1935. The nutritional requirements of trout. Trans. Am. Fish. Soc. 65, 359-375.

(28) TUNISON, A. V.; PHILLIPS, A. M.; SHAFFER, H. B.; MAXWELL, J. M.; BROCKWAY, D. R.; and McCAY, C. M.

1944. The nutrition of trout. Fish. Res. Bull. No. 6, N. Y. State Conserv. Dept., Albany, N. Y., Cortland Hatchery Rept. No. 13, 20 pp.

(29) EINARSEN, A. S. and ROYAL, L.

1929. What shall we feed? Trans. Am. Fish. Soc. 59, 268-271.

(30) McCAY, C. M.

1937. Observations on the nutrition of trout. Prog. Fish Cult. No. 30, 1-24.

(31) HAGEN, W.

1940. Suiting the diet to the hatchery. Prog. Fish Cult. No. 51, 11-15.

(32) GUTSELL, J. S.

1939. Fingerling trout feeding experiments, Leetown, 1938. Prog. Fish Cult. No. 45, 32-41.

(33) DAVIS, H. S.

1935. Cheaper trout foods. Prog. Fish Cult. No. 9, 7-10.

(34) WILKINSON, J. T.

1938. Notes on the use of supplements for fresh meat in the propagation of brook, rainbow, and brown trout in Michigan. Trans. Am. Fish. Soc. 68, 96-117.

(35) WALES, J. H.

1935. The feeding of trout in California hatcheries. Trans. Am. Fish. Soc. 65, 305-308.

(36) WALES, J. H. and BLISS, R.

1936. Progress report of trout feeding experiments, 1936. California Fish and Game 23, No. 2, 138-143.

(37) THOMPSON, W. T.

1929. A rival to liver. Trans. Am. Fish Soc. 59, 168-173.

(38) DAVIS, H. S., and LORD, R. F.

1929. The use of substitutes for fresh meat in the diet of trout. Trans. Am. Fish. Soc. 59, 160-167.

(39) FIELD, J. B.; HERMAN, E. F.; ELVEHJEM, C. A.; and SCHNEBERGER, E.

1944. Note on a controlled feeding technique in nutrition studies in trout. Copeia, No. 3, 184.

(40) TUNISON, A. V.; PHILLIPS, A. M.; McCAY, C. M.; MITCHELL, C. R.; and RODGERS, E. O.

1939. The nutrition of trout. N. Y. State Conserv. Dept., Albany, N. Y., Cortland Hatchery Report No. 8, 32 pp.

(41) McLAREN, B. A.; HERMAN, E. F.; and ELVEHJEM, C. A.

1947. Nutrition of trout, studies with practical diets. Proc. Soc. Exptl. Biol. Med. 65, 97-101.

(42) FIELD, J. B.; HERMAN, E. F.; and ELVEHJEM, C. A.

1944. Increased growth produced by gelatin in trout fed meatless diets. Proc. Soc. Exptl. Biol. Med. 55, No. 3, 222-225.

(43) HEARD, R. D. H.

1930. Investigations on the nutrition of speckled trout. Trans. Am. Fish. Soc. 60, 140-145.

(44) McCAY, C. M. and DILLEY, W. E.

1927. Factor H in the nutrition of trout. Trans. Am. Fish. Soc. 57, 250-260.

(45) McCAY, C. M.

1939. The vitamins. (A symposium). pp. 599-600, The American Medical Assoc., Chicago.

(46) McCAY, C.M.; BING F.C.; and DILLEY, W.E.

1927. The effect of variations in vitamins, protein, fat and mineral matter in the diet upon the growth and mortality of eastern brook trout. Trans. Am. Fish. Soc. 57, 240-250.

(47) McCAY, C.M.; DILLEY, W.E.; and CROWELL, M. F.

1929. Growth rates of brook trout reared upon purified rations, upon dry skim milk diets, and feed combinations of cereal grains. J. Nutrition 1, No. 3, 233-246.

(48) NORRIS, E. R. and DONALDSON, L. R.

1940. The effect of fat and cholesterol on the growth of young salmon. Am. J. Physiol. 129, 214-218.

(49) McCAY, C. M.; TUNISON, A. V.; CROWELL, M.; TRESSLER, D. K.; McDONALD, S. P.; TITCOMB, J. W.; and COBB, E. W.

1931. The nutritional requirements of trout and chemical composition of the entire trout body. Trans. Am. Fish. Soc. 61, 58-82.

(50) DONALDSON, L. R. and FOSTER, F. J.

1936. Processing of fishery products into fish food. Prog. Fish. Cult. No. 19, 1-6.

(51) DONALDSON, L. R.

1935. The use of salmon by-products as food for young king salmon. Trans. Am. Fish. Soc. 65, 165-171.

(52) WALES, J. H. and MOORE, M.

1937. Progress report of trout feeding experiments, 1937. California Fish and Game 24, No. 2, 126-132.

(53) TUNISON, A. V. and McCAY, C. M.

1933. The nutritional requirements of brook trout. Trans. Am. Fish. Soc. 63, 167-177.

(54) McCAY, C. M.; TITCOMB, J. W.; COBB, E. W.; CROWELL, M. F.; and TUNISON, A. V.

1930. The nutritional requirements of trout. Trans. Am. Fish. Soc. 60, 127-139.

(55) PHILLIPS, A. M.; TUNISON, A. V.; FENN, A. H.; MITCHELL, C. R.; and McCAY, C. M.

1940. The nutrition of trout. Cortland Hatchery Rept. No. 9, 30 pp., N. Y. State Conservation Dept., Albany, N. Y.

(56) TUNISON, A. V.; PHILLIPS, A. M.; BROCKWAY, D. R.; DORR, A. L.; MITCHELL, C. R.; and McCAY, C. M.

1941. The nutrition of trout. Fish. Res. Bull. No. 1, N. Y. State Conserv. Dept., Bur. Fish Culture, Albany, N. Y., Cortland Hatchery Rept. No. 10, 19 pp.

(57) HEWITT, E. R.

1936. Identification of factor "H" in the nutrition of trout. Trans. Am. Fish. Soc. 66, 291-297.

(58) SYMPOSIUM

1926. Symposium on fish culture. Trans. Am. Fish. Soc. 56, 130-155.

(59) TUNISON, A. V.; BROCKWAY, D. R.; MAXWELL, J. M.; DORR, A. L. and McCAY, C. M.

1942. The nutrition of trout. Fish. Res. Bull. No. 4, N. Y. State Conserv. Dept., Bur. Fish Culture, Albany, N. Y., Cortland Hatchery Rept. No. 11, 45 pp.

(60) SIMMONS, R. W. and NORRIS, E. R.

1941. Xanthopterin, the fish anemia-factor. J. Biol. Chem. 140, No. 2, 679-680.

(61) NORRIS, E. R. and SIMMONS, R. W.

1945. The hematopoietic activity of xanthopterin in young salmon. J. Biol. Chem. 158, No. 2, 449-453.

(62) McCAY, C. M.

1934. Growth. Prog. Fish. Cult. No. 1, 2-7.

(63) SEKINE, H. and KAKIZAKI, Y.

1930. On a synthetic diet for use in fish culture. I. Coefficient of utility of dietary protein. J. Imp. Fisheries Exptl. Sta. 1, No. 1, 143-153; Biol. Ab. 6, No. 3, 6824.

(64) SEKINE, H. and KAKIZAKI, Y.

1931. Biochemical studies on salmonidae, VII. J. Agr. Chem. Soc. Japan 7, 36-40; C.A. 25, No. 13, 3401 (1931).

(65) TITCOMB, J. W.; COBB, E. W.; CROWELL, M. F.; and McCAY, C. M.

1928. The nutritional requirements and growth rates of brook trout. Trans. Am. Fish. Soc. 58, 205-231.

(66) HEWITT, E. W.

1937. Some recent work on fatty livers in trout. Prog. Fish Cult. No. 27, 11-15.

(67) McCAY, C. M. and TUNISON, A. V.

1935. Report of experimental work at the Cortland (N.Y.) experimental hatchery for the year 1934. Prog. Fish Cult. No. 7, 8-9.

(68) HESS, W. N.

1935. Reducing the islets of the pancreas of fish by means of diet, lack of exercise and over eating. J. Exptl. Zool. 70, No. 2, 187-195.

(69) DONALDSON, L. R.

1943. Histological studies of the pancreas and associated tissues of wild and experimentally fed young chinook salmon. Am. J. Physiol. 138, No. 3, 560-564.

(70) McCAY, C. M.; TUNISON, A. V.; CROWELL, M.; and PAUL, H.

1936. The calcium and phosphorous content of the body of the brook trout in relation to age, growth, and food. J. Biol. Chem. 114, No. 1, 259-263.

(71) WALES, J. H.

1944. Fresh ocean fish as a trout diet. California Fish and Game 30, No. 1, 43-48.

(72) DONALDSON, L. R. and FOSTER, F. J.

1937. Notes on the use of kelp meal in the diets of young salmon. Prog. Fish. Cult. No. 27, 3-7.

(73) TITCOMB, J. W.; COBB, E. W.; CROWELL, M.; and McCAY, C. M.

1929. The relative value of plant and animal by-products as feeds for brook trout and the basic nutritional requirements of brook trout in terms of proteins, carbohydrates, vitamins, inorganic elements and roughage. Trans. Am. Fish. Soc. 59, 126-145.

(74) DONALDSON, L. R. and FOSTER, F. J.

1937. The use of oat flour combined with salmon meal in the diet of fingerling silver salmon. Prog. Fish. Cult. No. 32, 1-6.

(75) DONALDSON, L. R. and FOSTER, F. J.

1941. Bulk foods in the diet of young salmon. Prog. Fish Cult. No. 53, 23-25.

(76) FOSTER, F. J.; PELNAR, J.; and HAGEN, W.

1939. Preliminary results of an experiment on the inclusion of apple flour in foods fed to young salmonoids. Prog. Fish Cult. No. 47, 49-51.

(77) DONALDSON, L. R. and FOSTER, F. J.

1939. Some experiments on the use of salmon viscera, seal meal, beef pancreas, and apple flour in the diets of young chinook salmon. Prog. Fish Cult. No. 44, 10-17.

(78) DONALDSON, L.R. and FOSTER, F. J.

1939. Some experiments in the use of beef liver, seal meal, salmon meal and apple flour in the diet of young chinook salmon. Prog. Fish Cult. No. 46, 12.

(79) VETTER, H.

1938. Meat substitutes for feeding trout. Allg. Fischerei-Zeitg. 63, No. 2; Prog. Fish Cult. No. 37, 26-27 (Review), April, 1938.

(80) DAVIS, H. S.

1927. Some feeding experiments with trout fingerlings. Trans. Am. Fish. Soc., 57, 281-287.

(81) HAEMPEL, O. and PETER, H.

1932. Vitamin requirements of fish. Biol. Generalis 8, 73-90; C.A. 26, No. 6, 1645 (1932).

(82) McCAY, C. M. and PHILLIPS, A. M.

1940. Feeds for the fish hatcheries. Prog. Fish Cult. No. 52, 18-21.

(83) BING, F. C.

1927. A progress report upon feeding experiments with trout fingerlings at the Connecticut State Fish Hatchery, Burlington, Conn. Trans. Am. Fish Soc. 57, 266-280.

(84) HAEMPEL, O.

1927. The significance of vitamins in the food of domestic animals, especially fish. Allg. Fischerei-Zeitg. 2, 20-23; Biol. Ab. 4, No. 2, 4135 (1930).

(85) KROCKERT, G.

1938. Production of a dry feed for the feeding of trout and testing it to determine the content of vitamins, mineral matter and hormones. Z. Fischerie Hilfswiss 36, 473-487; Chem. Zentr. No. 2, 4391 (1939); C. A. 35, 6325[9] (1941).

(86) WOLF, L. E.

1945. Dietary gill disease of trout. Fish. Res. Bull. No. 7, N. Y. State Conserv. Dept., Bureau Fish Culture, Albany, N. Y., 32 pp.

(87) HAEMPEL, O. and PETER, H.

1927. Studies on the vitamin requirement of salmonidae. Biol. Generalis 3, 773-790; Biol. Abstracts 3, No. 4-6, 6056 (1929).

(88) WOLF, L. E.

1942. Fish-diet disease of trout. A vitamin deficiency produced by diets containing raw fish. Fish. Res. Bull. No. 2, N. Y. State Conserv. Dept. Bur. Fish Culture, Albany, N. Y., 16 pp.

(89) WOODBURY, L. A.

1942. Vitamin B deficiency in hatchery reared rainbow trout. Trans. Am. Fish. Soc. 72, 30-34.

(90) SEALOCK, R. R.; LIVERMORE, A. H.; and EVANS, C. A.

1943. Thiamine inactivation by the fresh-fish or chastek-paralysis factor. J. Am. Chem. Soc. 65, 935-940.

(91) LIECK, H. and AGREN, G.

1944. Thiamine-inactivating factor in some species of Swedish fish. Acta Soc. Physiol. Scand. 8, 203-214; C. A. 39, No. 21, 4931 (1945).

(92) SCHNEBERGER, E.

1941. Fishery research in Wisconsin. Prog. Fish Cult. No. 5, 14-17.

(93) GUTSELL, J. S.

1940. Frozen fish in hatchery diets may be dangerous. Prog. Fish Cult. No. 48, 28-32.

(94) MELNICK, D.; HOCHBERG, M.; and OSER, B. L.

1945. Physiological availability of the vitamins. J. Nutrition 30, No. 2, 81-88.

(95) BHAGVAT, K. and DEVI, P.

1944. Anti-thiamine factor in carp. Indian J. Med. Res. 32, 123-130.

(96) KRAMPITZ, L. O. and WOOLLEY, D. W.

1944. The manner of inactivation of thiamine by fish tissue. J. Biol. Chem. 152, 9-17.

(97) AGREN, G.

1945. Purification of the thiamine-inactivating fish factor. Acta. Soc. Physiol. Scand. 9, 306-312; C. A. 39, No. 22, 5260[8] (1945).

(98) AGREN, G.

1945. Action of the thiamine-destroying fish factor. Acta. Soc. Physiol. Scand. 9, 221-233; C. A. 39, No. 22, 52601 (1945).

(99) PHILLIPS, A. M. and BROCKWAY, D. R.

1947. This question of anemia. Prog. Fish Cult. 9, No. 3, 151-154.

(100) SMITH, R. T. and QUISTORFF, E.

1941. Calomel in the diet of hatchery salmon. Prog. Fish Cult. No. 51, 24-26.

(101) DONALDSON, L. R. and FOSTER, F. J.

1937. A summary table of some experimental tests in feeding young salmon and trout. Trans. Am. Fish. Soc. 67, 262-270.

(102) FOERSTER, R. E.

1932. Artificial food rations for Sockeye salmon. Trans. Am. Fish. Soc. 62, 223-238.

(103) DAVIS, H. S.

1932. The use of dry foods in the diet of trout. Trans. Am. Fish. Soc. 62, 189-196.

(104) DEUEL, C. R.

1935. The use of fish meal, conttonseed meal, meat meal, salmon egg meal and dried skim milk in trout diets. Prog. Fish Cult. No. 11, 19-20.

(105) DEUEL, C. R.

1935. The use of fish meal, cottonseed meal, meat meal, salmon egg meal, and dried skim milk in trout diets. Trans. Am. Fish. Soc. 65, 161-164.

(106) PHILLIPS, A. M. and HEWITT, G. S.

1943. Evaluation of salmon flesh and salmon viscera in the diet of chinook salmon fingerlings. Trans. Am. Fish. Soc. 73, 63-69.

(107) DONALDSON, L. R. and FOSTER, F. J.

1938. Comparative feeding values of some of the meals fed to fish. Prog. Fish Cult. No. 40, 20-23.

(108) DONALDSON, L. R. and FOSTER, F. J.

1939. Some experiments on the use of fresh beef blook as a substitute for beef liver in the diet of young chinook salmon (Oncorhynchus tschawytscha). Prog. Fish Cult. No. 47, 46-49.

(109) DAVIS, H. S. and LORD, R. F.

1930. Experiments with meat and meat substitutes as trout food. U. S. Dept. Comm., Bur. Fish. Doc. No. 1079, 123-147.

(110) WALES, J. H. and LEWIS, R. C.

1935. Progress report of trout feeding experiments. Calif. Fish and Game 21, No. 2, 110-123.

(111) WALES, J. H. and LEWIS, R. C.

1935. Progress report of trout feeding experiments, Calif. Fish and Game 22, No. 2, 111-117.

(112) CRAWFORD, D. R. NIZAM, A. R.

1929. Fish meals as food for salmonoid fishes. Univ. Washington Publication, Fisheries 2, No. 5, 51-72.

(113) THOMAS, W. H.

1935. Neosho offers interesting comments on feeding. Prog. Fish Cult. No. 9, 11-12.

(114) LOOFF, TED

1936. Food mixing gadget. Prog. Fish Cult. No. 21, 28.

(115) HESS, WALTER N.

1937. Production of nutritional cataract in trout. Proc. Soc. Exptl. Biol. and Med. 37, No. 2, 306-309.

(116) McLAREN, BARBARA A., KELLER, ELITHABETH,; O'DONNELL, D. JOHN,; and ELVEHJEM, C. A.

1947. The nutrition of rainbow trout. I. Studies of vitamin Requirements. Arch. Biochem. 15, No. 2, 169-178.

(117) McLAREN, Barbara A.; KELLER, Elizabeth, O'DONNELL, D. John; and ELVEHJEM, C. A.

1947. The nutrition of rainbow trout. II. Further studies with purified ration. Arch. Biochem. 15, No. 2, 179-185.

(118) GUTSELL, JAMES S.

1948. Cod-liver oil in the diet of trout. Prog. Fish Cult. 10, No. 2, 81-83.

(119) PHILLIPS, A. M.; TUNISON, A. V.; and BROCKWAY, D. R.

1948. The utilization of carbohydrate by trout. Fish. Res. Bull. No. 11, 44 pp.

(120) PHILLIPS, A. M.,; BROCKWAY, D. R.,; RODGERS, E. O.,; ROBERTSON, R. L.; GOODELL, HERBERT,; THOMPSON, J. A.; and WILLOUGHBY, HARVEY.

1947. The nutrition of trout. Fish. Res. Bull., No. 10, Cortland Hatchery Rept., No. 16, 35 pp.